Molluscs of the Peel-Harvey estuarine system, with a comparison with other south-western Australian estuaries.

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ABSTRACT

Thirty-four mollusc species are recorded from the Peel-Harvey estuarine system; 13 are marine, 9 of marine affinity, 9 estuarine, and 1 freshwater (2 were undetermined). The number of marine and marine affinity species in the system is low compared to some of the other areas of southwestern Australia. Factors limiting the numbers of these species were considered to be the lack of varied habitat types, geographical location and the rigorous temperature and salinity regime. Eleven estuarine mollusc species are widespread in southwestern Australia; nine were recorded in Peel-Harvey. Two of these, *Hydrococcus brazieri* and *Arthritica semen* are numerically dominant in the system.

INTRODUCTION

Estuaries have been defined by Pritchard (1967) as "semi-enclosed coastal bodies of water which have a free connection with the open sea and within which seawater is measurably diluted with freshwater from land drainage". The animals that inhabit this intermediate zone between the sea and freshwater are predominately euryhaline marine forms which are able to adapt to the rigors of the estuarine environment. A few freshwater species inhabit upstream estuarine areas if they can tolerate the increased salt concentration. In addition there are a few true estuarine species which are not found in other habitats (Day, 1967).

Rochford (1915) divided Australian estuaries into 3 types characterized by their freshwater flow: (1)summer flood, winter drought; (2)winter flood, summer drought; and (3) estuaries with no well defined seasonal flood or drought. South western Australian estuaries are in the second category. The dominant features of these estuaries are rainfall which is restricted to the winter months and poorly developed tidal oscillation (Spencer, 1956). Hodgkin (1978) emphasized the seasonality of salinity variations; animals are subjected to seasonal variations rather than diurnal ones. These are of the same timescale as the life-spans of the animals and mean that an animal cannot simply "close-

up" for a brief period during unfavourabl conditions.

Little is known of the molluscs of southwestern Australia estuaries. There are available names for most of the large species but some taxonomic problems remain; the taxonomy of many of the micro-molluscs has not yet been completed. Faunal lists have been prepared of the molluscs of the Blackwood estuary (Wallace,1975) and the Swan estuary (Chalmer, Hodgkin and Kendrick, 1976). In addition there are faunal lists for the marine embayments of Oyster Harbour and Princess Royal Harbour (Roberts and Wells, 1980). Hodgkin (1977) drew on the available distributional data to compare the molluscs of southwest estuaries.

In 1976 the Western Australian Department of Conservation and Environment began an intensive investigation of the ecology of the Peel-Harvey estuarine system. As part of that programme a three year study of the Peel-Harvey molluscs was undertaken (Wells, Threlfall and Wilson, 1980). The first step in the study, reported here, was to document the molluscan fauna of Peel-Harvey. Subsequent papers will deal with the biology of the dominant molluscs of the system.

HYDROGRAPHY OF THE PEEL-HARVEY ESTUARINE SYSTEM

The Peel-Harvey estuarine system is a small body of water with an area of approximately 130km. It is located 80 km south of Perth at 32°36'S and 115°42'E and consists of two distinct but connected parts. The largest body of water in the system is Peel Inlet (Figure 1) with an area of 70 km^2. The Inlet is circular and shallow with a maximum depth of 2m. Shallow platforms less than 0.5 m depth fringe the margins of Peel Inlet and account for over half of the total area. Harvey Estuary is a shallow coastal basin with an area of 60 km^2. There is an inlet channel, Mandurah Channel, leading from Peel Inlet to the sea at the town of Mandurah. The inlet channel has deltas at both ends.

Freshwater inflows into Peel Inlet occur from the Serpentine River and Murray River. Both are tidal in their lower reaches, and both have deltas at their mouths in Peel Inlet. Harvey Estuary originally received all the outflow of the Harvey River, but the upper part of the river has been diverted and now flows directly into the sea. The total freshwater runoff into the Peel-Harvey estuarine system averages 430 x $10^6 m^3$/year, with 364 x $10^6 m^3$ coming from the Murray River. The freshwater inflow varies considerably from year to year, with the observed extremes for the Murray River being 60 to 1100 x $10^6 m^3$/year. The river flow is strongly seasonal, with 95% occurring in the months of June to September (Hodgkin, pers. comm).

Seasonality of the freshwater inflow causes substantial changes in the salinity of the system during the year. The water of Harvey Estuary is nearly fresh during the winter and salinities in Peel Inlet briefly reach 5%o. With the lack of freshwater inflow and the increased evaporation in summer Peel Inlet and Harvey Estuary become hypersaline with salinities above 50%o for several months.

Daily tides in southwestern Australia are les than 1m and water level is often substantially altered by meteorological conditions (Hodgkin and Dilollo, 1958). In Peel Inlet tidal action is reduced and daily variations are less than 0.1m Meteorological conditions cause changes of up to 0.5m over periods of 5 to 15 days.

MATERIALS AND METHODS

Several collecting trips were made from December 1976 to March 1977; general collecting was done in all seasons during the next three years as time permitted. A two year sampling programme was conducted at Coodanup on Peel Inlet from March 1977 to February 1979 at a station 100m from shore. A corer with an area of 98.5 cm^2 was used to remove sediment to a depth of 2cm. Samples were sieved through a 1mm mesh in the field and the material was searched in the laboratory for live molluscs. Molluscs in other southwestern estuaries were collected in December 1979. A search of the collections of the Western Australian Museum provided additional distributional records.

RESULTS

Thirty-four species of molluscs were recorded in the Peel-Harvey estuarine system

(Table 1); 1 chiton, 21 gastropods, and 12 bivalves.

Chalmer *et al.* (1976) developed the following classification for molluscs in the Swan estuary based on a subjective assessment of their distributional patters and salinity tolerances.
Marine species: those which occur in estuaries for only short periods or are present only at irregular intervals.
Species of marine affinity: those with an essentially marine distribution but which also occur frequently in estuaries.
Estuarine species: those that do not occur in marine or freshwater areas.
Freshwater species: those that never occur in marine areas; they may be found in the upper reaches of estuaries.

The categories are essentially those proposed by Day (1951) except for the absence of his fifth category of migratory species.

The classification of Chalmer *et al.* (1976) and Roberts and Wells (1980) were applied to the species in the Peel-Harvey estuarine system (Table 2). There is a general progression from the large number of marine and marine affinity species collected at Mandurah to the Harvey River, in which only a single freshwater species was found. All 9 of the estuarine species were recorded in Peel Inlet; 3 estuarine species were collected in Harvey Estuary and 3 at Mandurah.

The locations of the other estuaries surveyed are shown on Figure 2; species recorded in these estuaries are listed on Table 3. The list is conservative; only species classified as estuarine are recorded. Only limited distributional data are available for most species of molluscs which occur in estuaries. Salinity tolerances have been studied only for *H. brazieri* and *A. semen* (Wells, Threlfall and Wilson, 1980), *Xenostrobus securis* and *X. inconstans* (Wilson 1968; 1969) and *Nassarius* spp (Smith, 1975). Because of this the classification of species is partly subjective and other authors might disagree. For example three cockles of the genus *Katelysia* occur on sandflats at the mouths of estuaries in the southwest. They are affected by lowered salinity for only brief periods during the year and we believe the species are better regarded as being of marine affinity; other authors might classify *Katelysia* as estuarine.

Table 3 shows there is a small suite of truly estuarine species in the southwest, most of which are widely distributed in the 12 estuaries and marine embayments surveyed. The Peel-Harvey system has the most estuarine species with 9 and several other estuaries have 7. The 9 species were recorded during a 3 year concentrated study during which several rare species were collected. *Batillariella estuarina* for example was recorded from a single live individual. Seven estuarine species were recorded from Broke Inlet in a single morning.

Table 4 compares the molluscan fauna of Peel-Harvey with the other areas of the southwest from which data are available. The total number of species in Peel-Harvey is much lower than in the Swan River estuary, Oyster Harbour and Princess Royal Harbour. This is due to the low number (22) of marine or marine affinity species in Peel-Harvey compared to the other areas, which had 86 to 122 species in the two categories.

DISCUSSION

The molluscan fauna of southwestern estuaries can be divided into three groups: true estuarine species which are adapted specifically to estuarine conditions; species which have invaded the estuary from adjacent marine areas (marine and marine affinity); and freshwater species present in the upstream areas. The freshwater species are a minor element of the fauna. In Peel Inlet several factors appear to limit the number of mollusc species that are marine or of marine affinity; habitat types, geographical location, temperature and salinity (Wells and Threlfall, 1980).

The estuarine system is shallow, with a largely sandy bottom, and there is little variation in the available habitats. The greatest diversity of molluscs in the system occurs on rocks at the mouth of the Mandurah channel. The mouths of the Swan River, Oyster Harbour and

Princess Royal Harbour are also areas of high diversity; relatively few species penetrate above the seaward portion of the estuary. The mouth of the Blackwood River is sandy. This eliminates rocky shore species and keeps the total number of species recorded in the estuary low (Table 4). The absence of hard substrata in Peel Inlet and Harvey Estuary prevents many species from occurring there.

The geographical location of Peel Inlet is in an area where there are few tropical species and the pool of available temperate species is less than in areas further south (Wilson and Gillett, 1979; Wells, 1980).

Many species which occur in the marine areas adjacent to the Peel-Harvey estuarine system are prevented from entering because of the variations in temperature and salinity in the estuary. Emery *et al.* (1957) have pointed out that the significant feature of these parameters is not the mean value, but rather the changes on a daily and seasonal basis and the rate at which they change. Salinity at Coodanup ranged from 2 to 53% and temperature from 10 to 27°C.

The diversity of molluscs in Peel Inlet during recent geological time was investigated by Treloar (1978). He found 25 species in the lower sediments (representing 6000 — 4000 years BP), most of which were marine or estuarine marine (here referred to as marine affinity). The fauna included species such as *Katelysia scalarina* and *K. rhytiphora* which are still common at the mouths of estuaries along the south coast of Western Australia from Oyster Harbour to the Blackwood River, but no longer occur on the west coast. While there were fluctuations in the number of mollusc species over time, the most dramatic decline in the number of species occurred about 4000 BP. The reasons for the reduction in species are not clear but could involve such mechanisms as changes in precipitation or reduced exchange with the ocean. *Notospisula trigonella* stands out in contrasts to the general loss of species. *N trigonella* has recently colonized southern Western Australia (Wilson and Kendrick, 1968) and is now common in Peel-Harvey.

Hydrococcus brazieri and *Arthritica semen* are the numerically dominant molluscs of the Peel-Harvey system, with mean densities at Coodanup of 9487/m^2 and 8105/m^2 respectively. *A. semen* is widespread in both Peel Inlet and Harvey Estuary but *H. brazieri* is absent in Harvey Estuary: both are present in almost all southwestern estuaries and they are often numerically dominant. They exhibit several adaptations which allow them to thrive in the estuarine environment: continuous reproduction, protective mechanisms for developing young, lack of a planktonic stage, rapid growth rates and short maturation times, and wide salinity and temperature tolerences (Wells, Threlfall and Wilson, 1980). The other dominant molluscs, mytilid mussels and the bivalve *Fluviolanatus amara*, which while not a mytilid is ecologically similar, have different strategies for survival in southwestern estuaries. Wilson (1968; 1969) demonstrated a wide salinity tolerance of *Xenostrobus securis* which was enhanced by the ability of the animal to close its valves during unfavourable periods. Mytilids were shown to have relatively long breeding periods (Wilson and Hodgkin, 1967) as does *F. amara* in Peel Inlet (Wells, Threlfall and Wilson, 1980). These species have separate sexes and expel gametes into the surrounding water. After a planktonic developmental stage the larvae settle and metamorphose into the juvenile form. Much larger numbers of gametes are produced in these species than in either *H. brazieri* or *A. semen*.

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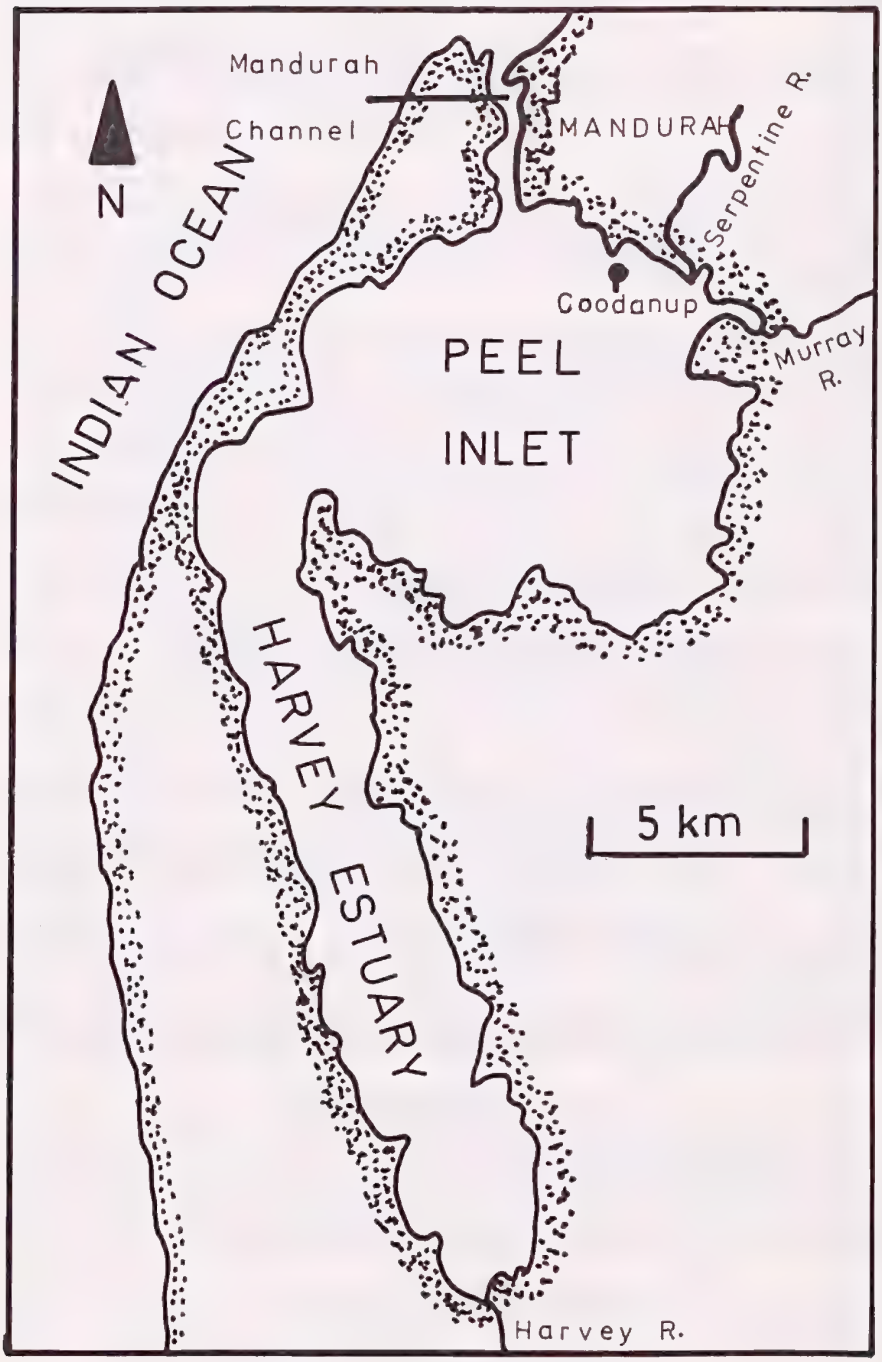
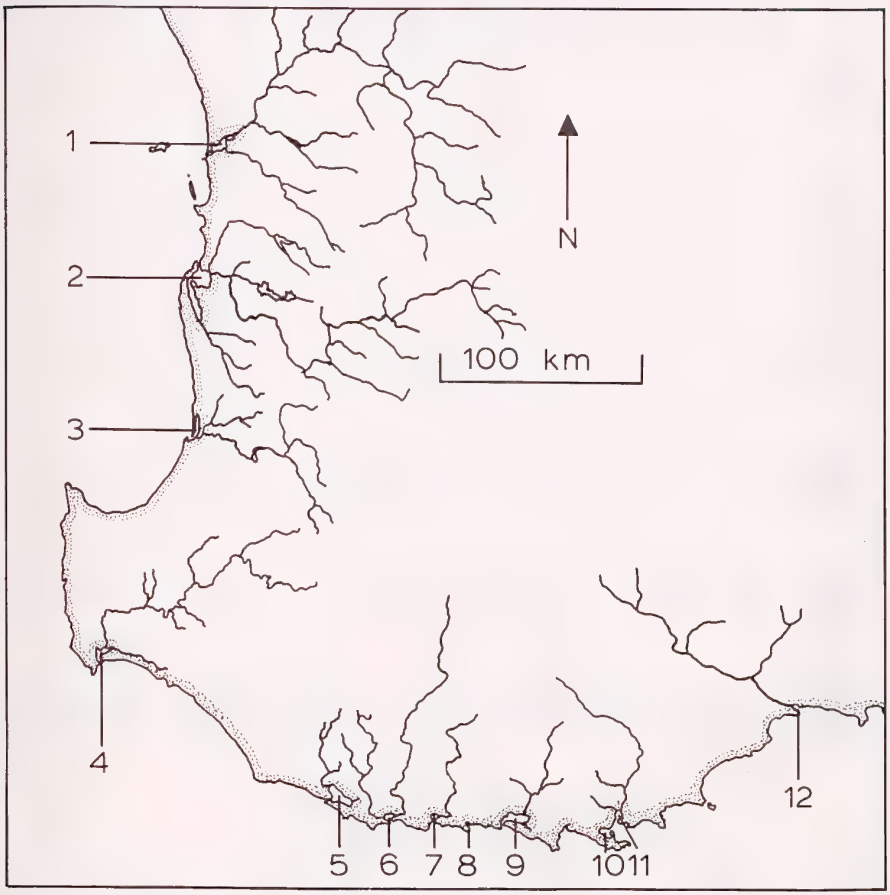


1. Map of the Peel-Harvey estuarine system.



2. Map of southwestern Australia showing the locations of estuaries in which species were collected. 1, Swan Estuary; 2, Peel-Harvey estuarine system; 3, Leschenault Inlet; 4, Blackwood Estuary; 5, Broke Inlet; 6, Nornalup Inlet; 7, Irwin Inlet; 8, Parry Inlet; 9, Wilson

Table 1. Mollusc species collected in the Peel-Harvey estuarine system.

Species	Habitat	Mandurah area	Peel Inlet	Harvey Estuary	Murray River	Serpentine River	Harvey River	Category
Class Amphineura								
Clavarizone hirtosa (Blainville, 1825)	Rocks	X	—	—	—	—	—	Marine
Class Gastropoda								
Notoacmea onychitis (Menke, 1843)	Rocks	X	—	—	—	—	—	Marine
Patella peronii (Blainville, 1825)	Rocks	X	—	—	—	—	—	Marine
Nerita atramentosa (Reeve, 1855)	Rocks	X	—	—	—	—	—	Marine
Littorina unifasciata Gray, 1826	Rocks	X	—	—	—	—	—	Marine
Hydrobia buccinoides (Quoy & Gaimard, 1834)	Sand	—	X	—	—	X	—	Estuarine
Hydrococcus brazieri (Tenison Woods, 1876)	Sand	—	X	—	—	—	—	Estuarine
Potamopyrgus sp.	Sand	—	X	X	—	—	—	Estuarine
Tatea preissii (Philippi, 1846)	High intertidal *Juncus*	X	X	—	—	—	—	Estuarine
Batillariella estuarina (Tate, 1893)	Sand	—	X	—	—	—	—	Estuarine
Diala lauta A. Adams, 1862	Sand	—	X	—	—	—	—	Marine affinity
Hipponix conica (Schumacher, 1817)	Shells	X	—	—	—	—	—	Marine
Polinices conicus (Lamarck, 1822)	Sand	X	—	—	—	—	—	Marine
Bedeva paivae Cross, 1864	Rocks	X	—	—	—	—	—	Marine affinity
Dicathais orbita (Gmelin, 1791)	Rocks	X	—	—	—	—	—	Marine
Nassarius burchardi								Marine

(Philippi, 1851)	Sand	X	—	—	—	—	—	affinity
Nassarius pauperatus (Lamarck, 1822)	Sand	X	—	—	—	—	—	Marine affinity
Odostomia sp.	Sand	—	X	X	—	—	—	Unknown
Liloa brevis (Quoy Gaimard, 1833)	Sand	X	—	—	—	—	—	Marine
Dendrodoris nigra (Stimpson, 1855)	Sand	X	—	—	—	—	—	Marine
Salinator fragilis (Lamarck, 1822)	Sand	X	X	—	—	—	—	Estuarine
Siphonaria luzonica Reeve, 1855	Rocks	X	—	—	—	—	—	Marine
Class Bivalvia								
Brachidontes ustulatus (Lamarck, 1819)	Rocks	X	—	—	—	—	—	Marine
Mytilus edulis planulatus Lamarck, 1819	Rocks	X	X	—	—	—	—	Marine affinity
Xenostrobus securis (Lamarck, 1819)	Logs	—	X	—	X	—	—	Estuarine
Westralunio carteri Iredale, 1934	Mud	—	—	—	X	—	X	Freshwater
Arthritica semen (Menke, 1843)	Sand	X	X	X	X	X	—	Estuarine
Notospisula trigonella (Lamarck, 1818)	Sand	X	X	X	—	—	—	Marine affinity
Macomona mariae (Tenison Woods, 1875)	Sand	—	X	—	—	—	—	Marine
Tellina deltoidalis Lamarck, 1818	Sand	X	X	—	—	—	—	Marine affinity
Tellina sp.	Sand	—	X	—	—	—	—	Unknown
Sanguinolaria biradiata (Wood, 1815)	Sand	X	X	—	—	—	—	Marine affinity
Irus crenata (Lamarck, 1818)	Rocks	X	X	—	—	—	—	Marine affinity
Fluviolanatus amara Laseron, 1956	Logs	—	X	X	X	X	—	Estuarine

1. *Hydrococcus graniformis* Thiele, 1928 is the name usually applied to this species but Dr. W.F. Ponder of the Australian Museum is preparing a paper synonymizing it with *H. brazieri*.

Table 2. Affinity groupings of molluscs found in the Peel-Harvey estuarine system.

Grouping	Mandurah	Area Peel Inlet	Harvey Estuary	Harvey R.	Total
Marine	12	1			13
Marine affinity	8	6	1		9
Estuarine	3	9	3		9
Freshwater				1	1
Undetermined		2	1		2
Total	23	18	5	1	34

Table 3. Distribution of "estuarine" species in southwestern Australian estuaries.

Species	Swan Estuary	Peel-Harvey estuarine system	Estuary Leschenault Inlet	Blackwood River estuary	Broke Inlet	Nornalup Inlet	Irwin Inlet	Parry Inlet	Wilson Inlet
Gastropods									
Batillariella estuarina		X		X				X	
Hydrobia buccinoides		X							
Hydrococcus brazieri	X	X	X	X	X	X	X		X
Potamopyrgus sp.	X	X	X	X	X	X	X	X	X
Salinator fragilis		X	X		X	X	X		X
Tatea preissi	X	X	X	X	X	X	X		X
Velacumantus australis	X								
Bivalves									
Fluviolanatas amara	X	X	X	X	X	X	X		X
Arthritica semen	X	X		X	X	X	X	X	X
Xenostrobus inconstans									
Xenostrobus securis	X	X	X	X	X	X	X		X

Species	Estuary Princess Royal Harbour	Oyster Harbour	Beaufort Inlet
Gastropods			
B. estuarina	X	X	
H. buccinoides		X	
H. brazieri	X	X	X
Potamoprygus sp.			X
S. fragilis	X	X	
T. preissi			
V. australis			
Bivalves			
F. amara			
S. semen		X	
X. inconstans	X	X	
X. securis		X	

Table 4. Affinity groups of molluscs in southwestern Australian estuaries. The sources of data are: Chalmer *et al.* (1976) — Swan River; Roberts and Wells, 1980 — Oyster Harbour and Princess Royal Harbour; Wallace (1975) — Blackwood River.

Species affinity	Swan	Peel-Harvey	Blackwood	Oyster Harbour	Princess Royal Harbour
Marine	64	13	3	69	52
Marine affinity	25	9	7	33	34
Estuarine	7	9	7	6	4
Freshwater	1	1	1	—	—
Total	97	32	18	108	90